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VI.

NOTES ON RECENT PROGRESS IN APPLIED SCIENCE.

THE science of to-day, like everything else, material or intellectual, is the child of the past, and our latest discoveries owe their very being to the old and almost forgotten labors and achievements of the earlier ages ; just as the earth of to-day owes its present condition and capacity for sustaining the complex existence of modern civilization, with all its refinement and beauty, to the long history of change and development beginning with the original chaos and passing through the periods of monstrous vegetable and animal life, of tree-ferns and of saurians, and the other eras of geologic change, and coming down through the dark ages of barbarous human development to our own time.

As one of our poets very beautifully expressed this idea :

What fiery fields of Chaos must be won,
  What battling Titans rear themselves a tomb,
What births and resurrections greet the sun,
  Before the rose can bloom!

And of some wonder-blossom yet we dream
  Whereof the time that is infolds the seed,—
Some flower of light, to which the rose shall seem
  A fair and fragile weed.

In consequence of this, it is hardly possible to describe any new development without large reference to the old foundation on which it is built, or the old material out of which it is formed.

Progress in Electric Science.

Thus the most remarkable and striking developments of late have been in subjects involving the principles of electric induction first brought to light by Faraday in 1831. The Bell telephone and the electric light of to-day are the direct applications of the principle first announced by Faraday in 1831.

A few words as to this principle and its connection with these applications will, then, come in good place, not only to make clear the latest developments in these directions, but also to prepare us for the next steps which may perhaps be taken before this present writing can reach the eye of its readers ; for so rapid is this progress that it even outstrips the marvelous rapidity of the compositor and the power-press.

In brief, then, this important principle is this : Whenever a conductor, such for example as a copper wire, is moved near a magnet so as to cut those directions in which iron filings arrange themselves about the poles of a magnet, and which are often called "lines of magnetic force "—whenever, we say, a conductor cuts these lines, a current of electricity is caused to flow through such a conductor. It is evidently immaterial whether the conductor is moved across the lines of force of a magnet at rest ; or, the conductor being at rest, the magnet with its lines of force is moved in reference to the conductor ; or, lastly, whether, both conductor and magnet being at rest, the lines of force are caused to move in reference to both magnet and conductor. In either case lines of force will be cut by a conductor, and a current will be developed as long as the cutting or relative motion between the conductor and lines of force continues. It is this simple principle which is at the foundation of all the electric-light machines and most of the telephones now in use.

Coils of wire are made to revolve rapidly near to powerful magnets, and by this means electric currents are generated which are then used, in one way or another, for the production of light. It must not, however, be forgotten that here, as everywhere else, the great doctrine of "conservation of energy" is maintained—that doctrine which found a prophetic expression in the proverb, one of whose homely forms was, "You can not *have* your cake and *eat* it too." In other words, and with special application to this case, you can not have an electric current and also the power required to generate it.

When the current begins to flow in the conductors or wire coils, it develops in them a powerful attraction for the magnets near which they are moved, and to continue the motion a great force must be continuously applied and expended.

Thus it comes about, that to produce electric currents with these magneto-electric machines, as they are called, a large amount of mechanical force must be applied, as for example the power of a steam-engine; and thus we get the electric current only by giving for it so much as its equivalent, of energy, which is derived from the fuel consumed in the furnace of the steam-boiler.

We are, therefore, getting the electric current at the expense of the coal consumed (making no allowance for losses), and, though this is very much less expensive than any method before known of obtaining an electric current, we would make a serious mistake if we forgot or neglected to include it in making any calculations as to the practicability and economy of electricity as a source of light or other effect.

Bearing this in mind, however, we find that recent improvements in the structure of magneto-electric machines have so developed their efficiency, that in the best forms as much as eighty per cent. of the energy applied to them is converted into electric current.

In other words, for every hundred horse-power expended in turning the machines, eighty horse-power is converted into electric force, and only twenty horse-power is wasted or lost in doing useless work, such as heating the machine itself.

Compared with other machines, this is a very wonderful performance. Our best steam-engines almost exactly reverse these figures; that is to say, our best steam-engines give us an available power of about twenty per cent. of the energy given out by the fuel burned in their furnaces, and waste eighty per cent. in heat thrown up the chimney and otherwise dissipated.

While, therefore, there is an immense margin for improvement in the economy and efficiency of our steam-engines, the magneto-electric machines have nearly reached the maximum possible of effectiveness, and any one who proposes to double their performance in this respect, either does not know what the good ones now accomplish, or does not understand the subject.

In applying the electric currents which these magneto-electric machines develop to the production of light, two principal means have been employed: first, the electric arc; second, the incandescence of a heated conductor.

The *electric arc* was first shown by Sir Humphry Davy in 1808, and is produced by interrupting a powerful electric current between two points of carbon. To accomplish this we have two pieces of carbon in contact with each other, and so connected with a galvanic battery or magneto-electric machine that the current flows through them; then, on separating the pieces of carbon gradually from each other, the electric current springs across the gap, carrying with it particles of carbon and carbon vapor, which make a flying bridge by which it continues to travel across.

In thus tearing off particles from one side and hurling them against the other, intense heat and light vibrations are occasioned in both poles or points, and in the flying fragments, and this is what constitutes the electric arc.

Such an arc may develop a light equal to that of five hundred or of twenty thousand candles, and is so far, much the most efficient and economical means by which electric force can be converted into light.

The best results as yet obtained show that for each horse-power expended in turning the magneto-electric machine a light equal to that of two thousand candles (or one hundred and twenty-five gas-burners) can be obtained.

A first-rate engine should not need more than three pounds of coal per horse-power per hour, so that in every case where a light of some hundreds of gas-burners in one place is required the light of the electric arc would be very economical. The difficulties which at present limit its use in this connection are the result of its great intensity and more or less unsteadiness, and the inconvenience of having a steam-engine in certain localities. Multitudes of ingenious inventors are busy devising electric lamps to overcome the former of these difficulties, and without doubt the electric-arc light will daily extend its field of illumination among our factories, workshops, and public buildings generally.

Electric incandescence, as a source of light, made its appearance at about the same time and in the same place as the electric arc, but it was first reduced to a practical shape about twenty years ago by M. de Changy in Paris, and by Mr. Moses G. Farmer in Salem, Massachusetts. Both of these gentlemen seem to have developed electric lamps operating by the incandescence of a metallic wire, and having an efficient automatic regulator by which their constancy of action was secured; but the great cost of electricity, produced at that time by the galvanic battery, caused the abandonment of all efforts to make any practical use of such apparatus. Now, however, that a relatively cheap source of electricity is found in the magneto-electric machine, these old plans have been revived, and we find in Mr. Edison's English patents a redevelopment of the same thing.

They all operate on the fact that when a powerful current of electricity traverses an insufficient conductor, as a wire or narrow strip of platinum, for example, the same is intensely heated, and so becomes luminous. Coils of wire, strips of platinum, or the like, are therefore so arranged that a current shall pass through them, and so make them luminously hot or incandescent. As this incandescence is greatest near the fusing-point of these substances, and their fusion would of course interrupt the action, various ingenious contrivances are adopted by which the current is automatically shut off or diverted if it approaches too near to this disastrous result. Thus, for example, the strip of incandescent metal itself so operates a lever that as soon as its expansion reaches a certain degree it closes a circuit, which diverts part of the current into another conductor.

There are a multitude of these contrivances, and almost every day sees new ones added to the list, but so far they have all been very elaborate, often complicated, and, as a rule, expensive instruments.

Another plan is to use, in place of a metal which *may* be fused, a thin rod of carbon, which can not be fused, and whose tendency to burn is overcome by inclosing it in a glass vessel filled with some gas which can not combine with it, nitrogen for example. Lamps of this nature have been largely experimented with, and inventors are still laboring upon them, but as yet the success obtained is not such as to warrant their practical introduction into actual use.

In all plans of obtaining light by electric incandescence so far published, the cost of the light has been many times greater than with the electric arc.

On the other hand, by incandescence, lights of moderate power, equal for example to one or two gas-burners, can be produced, and this would be of course a property of essential importance in any general use of electricity for domestic lighting.

It is on these subjects that several of the most ingenious minds of the day are now working, and what we have above stated not only gives the present state of the problem, but will prepare the reader to comprehend the new developments as they appear.

The next application of Faraday's discovery of magneto-induction is found in the Bell telephone. In this instrument a series of electric currents is developed by the movements of a thin plate of iron in front of a steel magnet, around whose end a wire is coiled. As the thin iron plate vibrates to the impulse received from the voice of one speaking near it, the lines of force about the magnet are caused to move, and so cut across the coils of wire, and consequently develop in them electric currents. These fluctuating electric currents, carried by a telegraph wire to a distant place, modify as they vary, the attraction of a similar magnet for a like thin iron plate, and thus this plate repeats the motions of the first one, and gives to the ear of the listener the motions which constituted the sounds in the spoken words uttered against the first iron plate.

Modifications in form or arrangement of parts have been made by various experimenters and inventors, but the same principle pervades all the telephones of this class.

Two other fundamentally different principles, however, have been and are now used in other classes of telephone :

First, the fluctuation of a current by the change in perfection of contacts by variations of pressure. This is found in Edison's carbon telephone, and in the microphone.

It was long ago shown, by Dr. Robison,* that what we commonly regard as contact between different bodies is very far from being absolute ; that, for example, one plate of smooth glass resting on another did not touch the first by about one five-thousandth of an inch, and that, to bring two pieces of glass an inch square into even approximate contact, a pressure of one thousand pounds must be exerted. Thus, if two conductors rest on each other, and a current passes between them, it must leap over this space and experience resistance to its passage in so doing. Any increase of pressure between the two surfaces will diminish this distance and increase the flow of the current by rendering its passage easier. This principle is applied in Mr. Edison's carbon telephone by using a little button of lampblack and a plate of platinum as the surfaces of contact between which an electric current is made to flow. If we speak against an elastic plate which presses these surfaces together, the vibrations communicated by the voice will vary this pressure, and correspondingly vary the current flowing. This varying current carried to a distant place will modify the action of a magnet on a thin iron disk, and so repeat the motions, sounds, or words which were the original cause of the fluctuations in the electric current. In place of this carbon button and platinum plate as a variable contact, we may have one piece of metal loosely resting on another, as, for example, one iron nail laid across another, and thus produce one of the most surprising forms of the microphone ; for, with such a rough combination as this, what we say to the loose nail will be heard by our friend miles away.

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* "System of Mechanical Philosophy," Edinburgh, 1822, vol. i., p. 247.

The other principle applicable to telephonic communication was no doubt involved in some of the early experiments of Mr. Elisha Gray, although first distinctly announced by Mr. Edison. It is this :

When an electric current passes between certain substances, it greatly modifies their friction. Thus, if we pass a current from a piece of platinum into a strip of paper moistened with potash solution, and try to draw the platinum along the surface of the paper while the current is being varied, we can not move it steadily, but it will go by jerks, because the friction will so vary that the platinum now drags and now slides. It is easy to see how this can be applied to the transmission of sound. Let the current be fluctuated by the voice, by the use of the carbon and platinum contact, for example, and then, at the other end of the line, make the same current pass from a platinum brake, connected with a sounding-board, into a roller covered with prepared paper, and kept constantly turning so as to draw the brake forward by friction. As the current varies, the friction varies ; and thus the sounding-board is variously pulled and made to vibrate, or, in other words, to sing.

It is just now announced that Mr. Edison has, by the use of this principle, produced a talking telephone which speaks louder than any other heretofore made, and can, in fact, be heard all over a large room.

Progress in Molecular Physics, or the Mechanics of the Atoms.

Among the most interesting developments in recent scientific research are those which seem almost to give us a view of the ultimate constitution of matter, and to be on the point of introducing us face to face with the original atoms or molecules out of which material substances are built.

The remarkable researches of Professor William Crookes, of London, which we may best indicate in a word as those grouping themselves about the "radiometer," are already old, but they have been followed up by the same investigator on a new line, with the most admirable results. Here, however, as elsewhere, we must go back to the older foundation in order truly to appreciate and comprehend the later superstructure.

Crookes's radiometer and related experiments showed essentially the following facts about the behavior of the atoms or molecules of gases and solid substances :

When a heated solid is surrounded by a gas, like air at its usual density, the rapid molecular vibrations of the hot solid, which constitute its heat, cause it to dash off or strike off those atoms or molecules of the air which run against it. For it must be remembered that the whole mass of air is believed to be made up of minute particles or molecules, perfectly elastic, and vibrating with great velocities, but so crowded together that no particle can travel far before it strikes against another, and so reverses and exchanges its motion. Indeed, if we could see the molecules or particles in a mass of air, the whole would shimmer, as it were, with the eternal, restless, back-and-forth motion of the innumerable flying particles.

Now, suppose that we have a body hot on one side and cold on the other, surrounded by air at ordinary density, what will happen?

The vibrating air-particles which strike on the hot side will be driven off with a greater velocity than they had on arriving, and those striking the cold side will only rebound with the same velocity they had before, and the difference in reaction between these two sets we might perhaps suppose would make the hot body move backward away from the hot side where it was kicking off the air-particles so violently. But, on further reflection, we will see that such a result ought not to follow ; for, though the hot surface of the body would drive itself back by its violent striking off of the air-particles, yet this action would be compensated by another, namely, the air-particles so driven off would, by reason of the greater motion they had received, fly farther, and carry off with them more of the surrounding air-particles than they would if they had only moved at the common rate. The result of this would be that they would be longer in coming back to strike again against the hot body, and would also have delayed the arrival of other particles which would otherwise have struck the hot body, and this action will exactly compensate and counteract the other so that the hot side of the body will have no tendency to cause motion in it. Now, however, let us suppose that we inclose this body hot on one side but cold on the other in a vessel and begin to pump out the air from around it.

As we exhaust the air the cloud of flying particles will get thinner and thinner, and each particle will move farther and farther before it reaches collision with one of its neighbors, and the particles dashed off by the hot side will keep back the general crowd of moving air-particles to a greater and greater distance. As long, however, as there *is* such an outlying and surrounding crowd of particles, in whose mass the heat-repelled molecules expend their force, the reaction produced in the hot side of the body, by driving these last-named particles violently off, will be exactly compensated by the corresponding diminution in the blows it would receive from this crowd of normally moving particles which are thus held off by the others.

When, however, the exhaustion reaches such a point that there are no longer particles enough to form this outlying crowd, then the struck particles, which are violently repelled, will encounter no others, but will fly all the way in a free path to the surface of the inclosing vessel.

Moreover, it will also be true at the same time that the air-particles which strike on the cold side of the body will likewise move in free paths, without other than occasional collision, until they strike on the surface of the containing vessel—for of course the whole interior of the exhausted vessel must be equally rarefied, and the particles equally scattered in all parts.

Now, then, it is evident that under these conditions a new set of results will follow. The hot side of the body, repelling or striking off the air-particles violently, will thereby drive itself back as a rower drives his boat forward by pushing the water back ; while, on the other hand, the cold side of the body would not repel or drive off the air-particles striking it with any such energy, and would not therefore cause in itself any such reactionary motion as would balance that developed by the hot side. The unequally heated body would therefore move, its hot surface retreating and its cold side advancing, as we might say.

Yet further : The particles violently thrown off from the hot side would strike the opposite side of the containing vessel more powerfully than would those more gently thrown back by the cold side ; and consequently, if the unequally heated body were fixed, and the containing vessel were free to move, it would move away from the hot side and toward the cold side of the interior body.

To prepare a body hot on one side and cold on the other is not difficult. Dr. Crookes first did this by taking a little package of sheets of mica, and coating this package on one side with lamp-black. When this was exposed to sunlight, the black side grew hotter than the other. Such little packages of mica, mounted like the paddles of a wheel, made the motive power of his radiometers, and moved round as though the black or hot side was backing away from the air in front of it.

By floating the glass vessel which contained the little wheel on water, and then preventing the wheel from moving by an appropriate use of magnets, he showed that the glass vessel would then turn round, as if driven away from the black or hot sides of the paddles.

By another arrangement, he also caused the current of repelled air-particles to turn round a sort of propeller-wheel.

By these and countless like experiments, we were for the first time introduced to air under such conditions that we could observe the behavior of its individual particles or molecules when they were acting not in mass, but each on its own account like elastic balls flying about between the cushions of a billiard-table, only without loss of motion and without rest.

Now, using the same highly rarefied air or other like gas as the material for his experiment, Dr. Crookes has shown what is its behavior when electricity, in place of heat, is the exciting cause of the motions studied.

He finds that just as a hot body caused violent motion in the air-particles which came in contact with it, so one electrically excited produces similar motions in the adjacent air-particles. As a result of these motions, the air-particles immediately around the excited body seem to drive away the mass of the air, and, by their continual bombarding or pommeling of the rest, keep them at a distance, which varies with the degree of electrical excitement, the rarefaction of the gas, and other conditions.

The limit of this "clearing," kept open in this way, is marked by a luminous area, whose light is supposed to be produced by the blows of the flying molecules upon the relatively stationary outlying crowd.

A house on fire, surrounded by a disorderly crowd, kept off to a certain distance by the clubs of an active police force, is an imaginary picture which might be, perhaps, in some sort suggestive of the state of affairs here supposed, only among the air-molecules the police keep off the crowd by "butting" at them.

When the exhaustion is carried to such an extent that the outlying particles, which constituted the crowd, are all removed, the excited ones run all the way to the walls of the vessel before they encounter anything to restrain their motion, and then, running their heads against this solid wall, they develop by the blow a very beautiful and peculiar phosphorescent light.

The motions of these particles are very accurately directed in straight lines at right angles to the excited surface, and thus they can be cut off from any part of the interior of the vessel by a screen of glass, mica, or other body, transparent or opaque. Moreover, they are capable of producing mechanical motion.

Thus, if a little paddle-wheel is hung in the interior of one of these vessels, in such a position that the storm of flying molecules is shaded off from half of its paddles, it will be driven round just as is an undershot water-wheel in a mill-race.

To describe all the remarkable experiments which have been made in this connection would fill this entire Journal, and we must, therefore, here leave this remarkable investigation, which seems to introduce us, like the microscope, to a new and wonderful world of the indefinitely minute.

HENRY MORTON.